CEO Characteristics and Technology Adoption in Smaller Manufacturing Firms

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1. Introduction

The adoption of new technologies, given the competitive advantages that it provides, takes on additional importance in the current context of business expansion and market globalization (Williams and Novack, 1990; Blois, 1988; Meredith, 1987; Thurow, 1987). Small manufacturing firms, vulnerable as they are to the increasing competitive pressures, are faced with a technological challenge. The delay observed in the adoption of new technologies could, in certain sectors, place the very survival of these companies into question (McMillan, 1987).

Much research has demonstrated the profound influence of the chief executive officer (CEO) on the strategic orientation of his firm (Miller and Toulouse, 1986b) and particularly on the adoption of innovations (Quinn, 1985b). Nevertheless, our current level of knowledge does not permit us to define with any degree of precision the CEOs distinctive characteristics and fundamental role in the adoption process or the actual form his influence takes during the adoption decision of new technologies.

It is therefore proposed to make an in-depth study of certain characteristics of CEOs, in light of their primary importance during the adoption of new technologies, especially in the context of small and medium-sized manufacturing firms.

2. Theoretical background and empirical evidence

At the general level, the link between chief executive officers and their firms is intuitively obvious. However, it is surprising how little empirical research has been done on this subject, whether in large companies (Beatty and Zajac, 1987) or in the smaller ones (Castaldi, 1986).

In the context of small and medium-sized companies (SMEs), no study of strategic activities can be carried out without taking into account the character of the CEO, as it will inevitably influence the strategic orientation of the firm (Adler, 1989; Mintzberg, 1988). The adoption of new technologies clearly falls into the realm of strategic activities (Shrivastava and Grant, 1985) and as such should be considered a topic of great interest. Yet, the link between technology adoption and CEO characteristics has not been demonstrated empirically in the specific context of small business.

2a. The influence of the CEO on the adoption of new technologies

The CEOs influence on the adoption of new technologies is paramount. In the case of small companies, the CEO is not only usually the first person to think of introducing information technologies, but he is also the one who makes the actual decision to computerize the company (Lefebvre et al., 1989). Even in very large companies and in the more general context of new technology adoption, the CEO plays a very active role (ECC, 1987; Maidique and Hayes, 1984; Roberts, 1969). In the course of an empirical study conducted in the hospital sector, Meyer and Goes (1987) concluded that innovations are more likely to be adopted and implemented within an organization's structures if the executive officers in charge of them are influential.

However, one also finds the opposite type of situation: one in which the CEOs influence is negative and constitutes one of the main obstacles to new technology adoption. Numerous researchers have deplored this situation, including Meyer and Goes (1987), Munro and Noori (1987), Bakos and Treacy (1986), Davis (1986), Skinner (1985, 1984, 1983), and Hayes and Wheelwright (1984). Comparative studies have also been carried out on the attitude of CEOs towards innovations. Some of them compare American and Japanese CEOs (Hayes and Wheelwright, 1984; Christiansen and Hogendorn, 1983; Marsland and Beer, 1983; Schonberger, 1982; Baranson, 1981; Hayes, 1981; Pascale and Athos, 1981; Wheelwright, 1981; Cole, 1980; Ishida, 1980) while others compare American

and German business leaders (Hayes and Wheelwright, 1984; Child et al., 1983; Limprecht and Hayes, 1982; Lawrence, 1980). All of them conclude that in North America top management is less well disposed to the adoption of new technologies than elsewhere.

Insofar as everything seems to confirm that, in certain situations, the CEO is one of the main obstacles to the adoption of new technologies, it is clearly necessary to study his contribution in more detail, examining four crucial aspects: his personal characteristics, his attitudes and personality traits, the peculiarities of his decision-making process, and the structural properties of the organization that are related to his influence.

The following paragraphs draw heavily on the innovation literature, since the adoption of new technologies is essentially one form of process innovation (Pennings, 1987).

2b. The CEOs personal characteristics and the adoption of innovations

A review of the literature shows three especially striking characteristics that play a role here. According to Jarymiszyn, Clark and Summers (1985), the characteristics that most hurt a CEOs performance are lack of experience with a particular firm, lack of experience with manufacturing (as opposed to administrative) functions, and lack of exposure to product or process technology.

The first of these three characteristics, i.e. the excessive mobility of upper-level managers in America, has been specifically denounced by Hayes and Abernathy in a landmark article entitled "Managing our Way to Economic Decline" (1980). The authors observe that companies tend to fill their senior executive positions with managers drawn from outside the firm. According to certain observers in other countries, for whom the idea of a long career with one company is completely natural, senior executives in America seem to be playing musical chairs, jumping from firm to firm. This mobility on the part of senior managers is said, among other things, to result in decisions based on inadequate and incomplete information and a tendency to plan only for the short term.

The previous employment experience of the CEO, as well as his academic background, which are generally not technically oriented, may constitute an obstacle to the adoption of new technologies (Dean, 1987; Bakos and Treacy, 1986; Benjamin et al., 1984; Gerstein and Reisman, 1982; Hayes and Wheelwright, 1984; Kantrow, 1980). These two factors could be considered as crucial since according to McMillan (1987) and Foster (1986), there can be no greater priority for the top management of tomorrow's high performing enterprises than an understanding of technological innovation.

These three personal characteristics of the CEO, which correspond to what we might call his identity card, will be measured by means of the six research variables presented in Figure 1 (the first set of independent variables).

2c. The CEOs attitudes and personality traits

Certain of a CEOs attitudes, what Skinner (1985) calls his mind set, are not conducive to new technology adoption: a marked aversion to risk (Litvack and Warner, 1987; Munro and Noori, 1987; Hayes and Wheelwright, 1984), and a negative attitude towards change in general and technological change in particular (Julien et al., 1988; Nasbeth, 1973).

This fear of risk can be explained in part by the CEOs perception of his control over the situation (Simon, 1979). Thus, there is a direct link between a lack of familiarity with technology on the part of the CEO and his perception of the risks and opportunities associated with it, which suggests that there is an interrelationship between the CEOs personal characteristics and his attitudes. On the other hand, a proactive attitude, or one of acceptance of product and/or process innovation, on the part of the CEO will tend to favour innovations (Khan and Manopichetwattana, 1989).

With regard to the CEOs personality traits, the notion of locus of control has often been associated with entrepreneurial behaviour (Brockhaus, 1982b, 1975; Shapero, 1975; Durand

and Shea, 1974) and has recently been identified as an influence on the innovative nature of a firm (Khan and Manopichetwattana, 1989; Miller and Toulouse, 1986a, 1986b; Miller et al., 1982). The locus of control (Rotter, 1966) reflects an individual's perception of the degree of control he is able to exercise over the events affecting him. Thus, a person whose locus of control is internal will be convinced that his own efforts have allowed him to change the course of events, whereas a person whose locus of control is external will be certain that destiny, fate or chance direct events. According to Miller et al. (1982), there is a positive correlation between the propensity to innovate and CEOs who give evidence of having an internal locus of control. This association has been demonstrated empirically in their work as well as in other, more recent, studies (Khan and Manopichetwattana, 1989; Miller and Toulouse, 1986a, 1986b).

Another personality trait, the need for achievement, has traditionally been associated with entrepreneurial qualities (Brockhaus, 1982a, 1980; McClelland, 1961), although recent empirical results provided by Roberts (1991, 1989) strongly challenge this association in the case of technological entrepreneurs. Furthermore, this quality does not necessarily entail success (Khan and Manopichetwattana, 1989) nor the adoption of innovations (Miller and Toulouse, 1986a).

One final character trait of leaders that is salient in the literature is their social and intellectual flexibility (Kets de Vries and Miller, 1984). This trait is closely linked to certain of the company's characteristics, as well as to certain aspects of the decision-making process. CEOs who are more flexible are generally found in companies which have a more informal structure and in which the decision-making process is more intuitive and risk-oriented (Miller and Toulouse, 1986b). Still, the association between CEO flexibility and innovation is far from significant (Miller and Toulouse, 1986b).

2d. The CEOs decision-making process and the adoption of innovations

The very way in which the decision to adopt new technologies is made can be one of the

strongest influences on the adoption process, according to several authors (Dean, 1987; Meyer and Goes, 1987; Pennings, 1987). As the CEO has considerable influence on the adoption of new technologies, it is logical to conclude that his involvement in the different stages of the decision-making process is of primary importance.

Rogers (1983) has proposed one of the best-known models of the innovation adoption process. According to Rogers, the process can be divided into five stages: becoming aware of the innovation under consideration, forming a favourable or unfavourable attitude towards it, deciding to adopt, implementing the innovation, and, finally, deciding whether or not to keep the innovation after it has been implemented. In the context of the adoption of process innovations, we are especially interested in the first three stages. Meyer and Goes (1988) propose that there are two stages to the process of deciding whether to adopt an innovation: the "intelligence" stage and the "evaluation/choice" stage. We will use this dichotomy in our examination of the CEOs decision-making process.

In the "intelligence" or research stage, systematic scanning of information, both internally and externally, is of the utmost importance. Many CEOs have a tendency to delegate these "technical details", which runs counter to the emphasis that many authors place on the involvement of top managers in the process, whether in the domain of information technologies (e.g. Bakos and Treacy, 1986) or production technologies (e.g. Farley et al., 1987; Meredith and Hill, 1987; Judson, 1984). Furthermore, it appears that not only are innovative ideas likely to arise in a context of greater sensitivity to the environment (Miller and Friesen, 1982; Utterback, 1971; Aguilar, 1967), but leaders of innovative firms give greater importance to a more widespread internal and external search for information (Khan and Manopichetwattana, 1989; Julien et al., 1988).

In the "evaluation/choice" stage, many CEOs appear to place too much emphasis on short-term profitability (Ginzberg and Vojta, 1985; Hayes and Wheelwright, 1984; Skinner, 1984; Harris et al., 1983; Hayes and Abernathy, 1980). This emphasis on short-term profit hinders the adoption of new technology. Basing themselves on an empirical study of 800

CEOs of large American companies, Harris et al. (1983) conclude that top managers who do not get involved in the technological process tend to underestimate the financial resources to be allocated to research-related activities and to favour those divisions that are likely to bring in immediate profits.

As well, certain authors have noted that the financial measures used to evaluate these profits are inadequate. For example, Dearden (1969), in a classic study, reviews the dysfunctional aspects of the emphasis on ROI (Return on Investment). For his part, Kaplan (1983, 1984a, 1984b) denounces the use of financial indicators derived from the accounting system, observing that they only signal short-term increases in profits. In the long term, firms may be reducing their economic power and their productive capital.

Many researchers (in particular, Kumar and Loo, 1988; Finnie, 1988; Hayes and Garvin, 1982) think that the financial evaluation techniques used during the course of the decision to acquire new manufacturing technologies constitute in themselves major obstacles to the process. Meredith and Hill (1987) qualify this position by suggesting that certain approaches to justifying new production technologies in particular are more appropriate in view of the level of complexity and integration of the more advanced production technologies.

In this analysis we will hold that a planning horizon more oriented towards the long term referred to here as futurity, methods of analysis less oriented towards the accounting of financial aspects and greater awareness of the firm's strategy on the part of the CEO are positively correlated with a firm's innovative character.

2e. Structural characteristics linked to the CEOs influence and the adoption of innovation

The structural characteristics of most interest to our research are those that are strongly influenced by the firm's CEO and that may ultimately lead to the adoption of new technologies.

The CEOs influence on the organizational structure of his firm is well known in the literature, especially when it comes to small companies (D'Amboise, 1989; Julien and Marchesnay, 1988). Some authors have gone even further and have demonstrated empirically the relationship between certain personality traits of the CEO and certain organizational configurations (Miller and Toulouse, 1986a; Miller and Dröge, 1986; Kets de Vries and Miller, 1984; Miller et al., 1982).

Many researchers have also shown the importance of certain specific organizational characteristics relative to the innovative capacity of firms. Thus, technocratization, i.e. the degree of technical and scientific knowledge to be found in a firm, is the characteristic most often associated with the adoption of technological innovations (Collins et al., 1988; Julien et al., 1988). With regard to the relationship between the technocratization of a firm and specific characteristics of its CEO, one might intuitively assume that there is a relatively tight relationship even though this has only been partially demonstrated.

Two other properties of firms associated with specific character traits of the CEO, namely, formalization and centralization, appear to be negatively associated with innovativeness (Cohn and Turyn, 1984; Hage and Aiken, 1970, 1967). It appears that decentralization stimulates creativity, even though one could provide some support for the opposite claim, i.e. that greater centralization can also facilitate the adoption decision, e.g. by limiting the number of people involved (Zaltman et al., 1973; Normann, 1971; Rogers and Shoemaker, 1971).

3. Methodology

3a. Choice of research variables and their operational measures

From our synthesis and analysis of the literature presented previously, we have retained five sets of variables (Figure 1). The first set constitutes the dependent variable, while the next four sets correspond to the independent variables.

The dependent variable

In the literature on innovation, many authors have noted that the results of research in this field are unstable, not convergent, uninterpretable and even contradictory (Meyer and Goes, 1988, 1987; Pennings, 1987; Kimberly, 1987, 1981; Ettlie et al., 1984; Tornatzky and Klein, 1982; Kimberly and Evanisko, 1981; Downs and Mohr, 1976).

The first difficulty is closely linked to the large number of definitions available for the term "innovation". For some people (e.g. Mohr, 1969), innovation represents a structural reorganization of the firm; for others (e.g. Julien et al., 1988), the introduction of a new production process; and for yet others (e.g. Miller and Toulouse, 1982), the creation of a new product. For Dewar and Dutton (1986), innovation is defined on the basis of the type of change it causes in the firm.

Given that innovation constitutes the dependent variable in the majority of studies, the problems created by the difficulty in grasping its nature have resulted, according to some authors, in viewpoints that are both fragmentary and contradictory (Dewar and Dutton, 1986). According to Downs and Mohr (1976), there are two classes of attributes that can be used to identify types of innovations: primary attributes, which relate to the object (the innovation) and are independent of the subject (the organization), and secondary attributes, which vary according to the perception that the subjects have of the object. Thus, certain attributes of an innovation might be the same for all organizations whereas others vary according to the type of organization in question. According to the authors, it is the secondary attributes that are most likely to indicate the innovative character of an organization. Nevertheless, in most studies no distinction is made between the primary and secondary attributes, which leads to uninterpretable results in many cases, as it is impossible to distinguish the effect of a given determinant on a particular type of innovation in a specific organization.

To compensate for the methodological difficulties associated with the choice of the dependent variable, we must identify the innovation being considered as precisely as possible, since there are fundamental differences between different types of innovation. We have retained innovations that have the same primary attribute: these innovations all correspond to computer-based technologies. The typology proposed in figure 2 is derived from empirical research (Statistics Canada, 1989; Lefebvre and Lefebvre, 1988) and includes applications associated with both computer-based administrative and manufacturing applications. These technologies are becoming more and more integrated, especially in the manufacturing sector, and it is therefore increasingly difficult to dissociate them (Taylor et al., 1986; Goldhar and Jelinek, 1985; Child et al., 1983).

As to the secondary attribute of these innovations, we have chosen the criterion proposed recently by Dewar and Dutton (1986) and Ettlie et al. (1984) in their empirical studies. According to these authors, an innovation may be radical or incremental, depending on the organizational and industrial contexts considered. To qualify the dependent variable, a group of experts familiar with the computerized processes generally found in the sector in question was asked to classify on a scale of 1 to 7 (where 1 = innovations of a more incremental nature and 7 = innovations of a more radical nature) each of the 21 innovations.

A weighted sum was then calculated based on the mean rank (r_i) attributed by the panel of experts to each of the 21 innovations, taking into account the presence or absence of each innovation for each firm considered. This weighted sum ($\sum_{i=1}^{21} r_i x_i$ where $x_i = 1$ for the presence of innovation i, and 0 for the absence of innovation i) is considered as a proxy of the degree of innovativeness of a firm and is the dependent variable used in this research.

The independent variables

The independent variables relate to certain characteristics of the firm's CEO that are directly linked to the adoption of innovations. The choice of these variables is justified by the theoretical considerations of the specific research problem presented above.

In the first set of variables are included six variables which allow one to measure the CEOs academic and professional experience, including his technical training (V5), his level of education (V6) and the extent of his job experience in the domain (V2, V3, V4). The first variable, that is, whether the CEO is also the owner of the company, represents one way of measuring the mobility of top executives, which is also captured by the second variable. This first variable has been retained since there appear to be many points of divergence between the profiles of CEO owners and CEOs who are not owners (Castaldi, 1986; Brockhaus, 1982, 1980; Decks, 1976). The only perceptual variable in the first set is the nature of the CEOs job-related experience (V4), as expressed by the measure proposed by Collins et al. (1988).

The second, third and fourth sets of variables consist of perceptual variables that are measured using constructs previously defined and tested (see Figure 1).

The control variables

The "a priori" control variables which were most readily available were the size measured in terms of the number of employees, and the sector of industrial activity. The "a posteriori" control variables were the presence of a head office and the size of the firm as measured by total annual sales.

3b. Choice of organizational context

Many studies have demonstrated the importance of structural characteristics during the adoption of innovations. For example, one must bear in mind the size of the firm (Rothwell, 1978) and the sector in which it operates (Chakrabarti, 1990). The failure to consider certain organizational characteristics may partly explain why certain research results are so contradictory.

The sample examined in this study is very precisely defined: it consists of manufacturing firms operating in Quebec in the plastics sector with between 10 and 200 employees. The arbitrarily set lower limit allows us to exclude the very smallest companies, which, as a group, have adopted very few process innovations. This type of a priori exclusion has also been practised in other studies for the same reasons (e.g. Statistics Canada, 1989). As well, these very small firms would not present some of the characteristics which most interest us, such as technocratization. The upper limit (less than 200 employees) forms one of the accepted definition of small and medium-sized companies (MIC, 1987).

It was decided that firms in the plastics sector would be studied because all the computerized process innovations presented in Figure 2 could potentially be used there. As well, this sector is penetrated to a relatively high degree by the innovations (Statistics Canada, 1989; Industrial Technology Institute, 1987). This sector is also very homogeneous, as the industry is concentrated largely on finished and semi-finished product manufacturing. Certain companies in this sector are involved in assembling and making plastic and composite components. Other companies transform raw materials by moulding operations (extrusion, injection and compression).

3c. Data collection and analysis

The panel of experts

The task of the panel of experts was to determine whether each of the 21 innovations presented in Figure 2 was of an incremental or a radical nature. A total of 20 experts from various domains (academic, public or parapublic and private) familiar with the particular context of small manufacturing firms took part in this survey. Each expert was contacted in person in order to ensure his participation as well as to familiarize him with the survey objectives.

The field study

The study was carried out by means of a questionnaire sent by mail and accompanied by an explanatory letter. The CEOs of 366 manufacturing firms, comprising all the small and medium-sized firms active in the plastics sector in Quebec, received this questionnaire. The questionnaire had previously been pretested on 10 people including CEOs of small manufacturing firms and academics. The choice of a firm's CEO as the one and only respondent is justified by the study's theoretical framework.

The participants were assured of strict confidentiality. The CEOs of 95 companies agreed to take part in the survey, a response rate of 26.3%, while five of the 366 questionnaires sent out were returned by the post office, stamped "address unknown". No register of names was kept. In order to respect the size criteria, one firm had to be excluded, as it was found to have more than 200 employees. An additional 20 firms reporting to a head office were also removed in order to avoid situations where technological choices could be dictated by the head office. All subsequent statistical analysis is therefore carried out on 74 firms.

Questionnaires were coded and the data carefully validated. Construct reliability was assessed for all multi-item variables. Cronbach coefficients ranged from .79 to .94, well exceeding the guidelines set by Van de Ven and Ferry (1980).

Data analysis was carried out in several consecutive steps. First, a comparative analysis of less innovative and more innovative firms based on their degree of innovativeness is presented in table 1. Since the two groups of firms differ significantly on a rather large number of variables, it was decided to investigate which of these best discriminate the two groups. To find out, two multivariate analyses were conducted. A varimax rotated factor analysis (table 2) was performed in order to uncover the structure within the variable sets and identify key underlying dimensions. The orthogonal factors obtained from the factor analysis were then entered in a stepwise discriminant analysis (table 3), thus eliminating problems of multicollinearity and providing a more comprehensive picture of what actually distinguishes firms with differing degrees of innovativeness.

4. Results and discussion

4a. Characteristics of CEOs in the more innovative firms

Table 1 shows the results of the comparative analysis carried out on the two groups of companies. The first group comprises firms that have scored lower than the median value on the degree of innovativeness and will be referred to as the "less innovative firms". The second group corresponds to the "more innovative firms" having scored higher than the median value. One should bear in mind that the degree of innovativeness captures the radical/incremental nature of the innovations considered.

Radical innovations demand a high level of internal expertise (Dewar and Dutton, 1986). As a result, a technical education and/or experience on the part of the CEO would favour their adoption. Table 1 clearly shows that this is the case: the CEOs of the more

innovative firms are significantly more likely to have a technical education or considerable functional experience in engineering or production as opposed to accounting or finance.

Radical innovations bring about major and profound changes that require a very positive attitude on the part of top management, as is clearly confirmed by table 1. A distinctly more favourable attitude towards technological change and risk, a more proactive attitude and an internal locus of control are all factors associated with the more innovative firms.

Radical innovations imply new elements, numerous uncertainties and unpredictable difficulties. These innovations are considered to be potentially disruptive, even threatening (Ettlie et al., 1984). As a result, it appears that their adoption in a small business context would necessitate a very intense and systematic research process, a planning horizon that is not simply focussed on the short term, more detailed analyses and a greater consciousness of the strategic orientation of the company. All of these predictions are borne out by the results shown in table 1. Note that external information has less weight than internal information for both groups.

Organizational structures and their relationship with the adoption of innovations have received the attention of a number of researchers (e.g. Collins et al., 1988). Nevertheless, there are contradictory results in terms of the type of innovation and the organizational context. Technocratization, reflecting the concentration of technical personnel, is said to favour incremental innovations because innovative efforts become institutionalized (Hage, 1980). In our opinion, this argument hardly applies to small and medium-sized companies but only to the larger firms studied by Hage. More recently, Ettlie et al. (1984) demonstrated that an aggressive technological policy linked to a concentration of specialists favoured radical innovations. In the same vein, Dewar and Dutton (1986) came to the conclusion that technocratization is the major element in the adoption of radical innovations, which our results undeniably support. The larger the number of technical employees, the better new ideas, new technologies and new procedures can be understood and implemented.

Although centralization is sometimes positively and sometimes negatively associated with innovation, we share the opinion of Dewar and Dutton (1986), according to whom the profound changes generated by innovations of a more radical nature necessitate a concentration of decision-making power. But radical innovations also demand an enormous amount of flexibility and adaptation, as the phrase "controlled chaos", used by Quinn (1985a) to describe this phenomenon, indicates. Although the concentration of decision-making power is very high for both groups, it is still somewhat higher for the radical group. Nevertheless, the element "formalization" reveals much larger differences, the "less innovative" group having more formal structures.

The analysis of table 1 would not be complete without examining the effect of the control variables, and especially the effect of size. The results of previous research have been divided with regard to the variable "size". Some studies have shown that small companies are the most innovative (Rothwell, 1978; Globerman, 1975). Nevertheless, the opposite hypothesis, i.e. that the degree of innovativeness is directly proportional to size, has been supported by work by Moch and Morse (1977), Armour and Teece (1980), and Kimberly and Evanisko (1981). One might suppose that the radical character of an innovation would have some effect on this relationship. Rothwell (1978) explains his results by emphasizing that small and medium-sized companies will not become innovative if this transformation requires a large financial investment. As well, it is clear that an increase in the size of a company is not likely to promote the type of structural adaptation that is favourable to the emergence of an innovative character (Moch and Morse, 1977; Zaltman et al., 1973; Inkson et al., 1970). In our study, size is not significantly associated with any particular type of innovation. As it happens, both groups of companies have a remarkably similar volume of sales. However, one should bear in mind that our sampled firms were quite homogeneous in terms of size.

4b. Classifying firms according to their degree of innovativeness

Results of the factor analysis (principal components with varimax rotation) satisfy the sampling adequacy test (Kaiser-Meyer-Olkin measure of 0.81) and are presented in table 2. The four factors obtained explain 74.6% of the variance, which is also satisfactory. The first factor, which in itself represents 49.4% of the explained variance, is largely dominated by the attitude towards risk, futurity and the systematic search for internal information, closely followed by proactive attitude and analytical ability. To a lesser degree, experience in engineering/production is also important. More marginally, we observe quite important contributions at the level of self-confidence and the systematic search for external information. The composition of this first factor is difficult to determine and we have chosen to limit ourselves to the six most important contributions. These contributions are highlighted in table 2. They refer at the same time to attitudes and characteristics of the decision-making process that are intimately linked to the entrepreneurial character and to the functional experience of the CEO in engineering/production. This suggests a specific entrepreneurial profile associated with the innovative and technological character of the industrial sector in which this research has been carried out. We have this called this first factor "entrepreneurial character".

The next three factors present little interpretive difficulty. The second factor clearly represents the functional experience in administrative fields. Equally obviously, factor three is dominated by the number of years of service (tenure) and factor four by a single variable related to organizational structure, centralization.

Let us note that educational level, awareness of strategy and two variables relating to organizational structure, technocratization and formalization, play a secondary role in the formation of factors. It seems as well that organizational structures as a whole have little influence in comparison to the CEOs characteristics. Will the four factors set out here allow us to discriminate among companies according to their degree of innovativeness? That is

what we will try to find out in the next section.

Discriminant analysis on the basis of a firm's level of innovativeness reveals the presence of three discriminating factors. These three factors allow us to correctly classify 76.1% of the firms, which is highly satisfactory. It is the "more innovative" group of companies which has a higher rate of classification (84.2%) and thus it is this group where the CEOs influence is most determinant. It should be noted that the two groups of companies were determined starting from the median, which does not leave any room for a grey area. The global classification rate would certainly have been much higher if we had taken the first and last quartiles.

On the basis of the results in this table, a number of observations become apparent. First, the CEO of a more innovative company has a very distinctive profile. Second, the entrepreneurial character (factor 1) constitutes the most important dimension permitting one to dissociate the firms not only according to the nature of the innovations adopted but also according to their degree of innovativeness. Third, organizational structures do not appear to be as important as the personal characteristics of the CEO, his attitudes and personality traits and the characteristics of his decision-making process. These three observations lead us to conclude that the CEO in a small firm typically plays the role of the champion of innovation, whose presence is a prerequisite for any innovation to be adopted (Ettlie et al., 1984; Chakrabarti, 1974). The notion of the champion goes back to Schön's 1963 study, which showed that, in order to overcome the indifference and resistance caused by major technological changes, it is necessary that there be a champion who will sponsor the ideas proposed, actively and vigorously promote them through the various communication channels and even risk his or her prestige and position to ensure the success of the adopted innovations. Schön specified that as soon as there is any discussion of a radical innovation, a champion is necessary.

Schön's opinion has been echoed in a number of domains and case studies (e.g. Dean, 1987; Ettlie et al., 1984). But champions of innovation can play various roles: there are

"technology champions", "project champions" and "executive champions" (Maidique, 1980). In the context of a small company, the CEO plays virtually all these roles (Dean, 1987; Maidique, 1980). One very recent study (Howell and Higgins, 1990) has shown that champions of technological innovations are significantly more likely to take risks and favour spending on innovations, characteristics which are very similar to those we have observed in the CEOs of more innovative firms.

5. Study Limitations

Admittedly, any field study will pose some problems of validity and reliability. In the framework of this research, the nature and size of the sample impose certain limits on the external validity of the results. The companies chosen belong to a specific industrial sector, and one that is relatively innovative with regard to the adoption of new technologies (Statistics Canada, 1989). Although we think that the results obtained here are generalizable to other sectors of activity, we cannot provide statistical proof of this.

The choice of CEOs as respondents is dictated by the very goal of this research; it is naturally impossible to check their honesty or to compare their perceptions to reality. Attempting to correct for this bias would require a methodological procedure that permitted the comparison of results from various levels of respondents, with certain levels confirming the CEOs perceptions, and the participation of an objective evaluator (who would have to come from outside the organization in question).

Within the adoption factor studied, we have restricted ourselves to the absolute minimum number of research variables. The addition of other variables would certainly have lowered the response rate but could, on the other hand, have enriched the interpretation of the results, making it possible to be more precise. Consider, for example, certain personality traits such as the need for accomplishment, which is very closely linked to entrepreneurial success (McClelland, 1961; Roberts, 1991) and which was recently shown to be a characteristic of champions of innovation (Howell and Higgins, 1990).

6. Conclusion

The analysis of the results obtained here allows one to make certain general statements which are of considerable interest. First of all, there are significant differences were found between CEOs of the more and of the less innovative firms. This suggests that if individual differences are not borne in mind when studying factors relating to the adoption of new technologies, certain crucial variables may be neglected, at least in the context of smaller businesses. Further, it would appear that the combined effect of a substantial number of entrepreneurial characteristics is required to promote innovativeness within a firm.

Secondly, results seem to show the primacy of variables related to the individual (i.e. the CEO) over structural characteristics such as centralization, technocratization and formalization which were previously found to be high predictors of change in automaticity (Collins et al., 1988). This could be explained by the differing organizational context of the two studies thus indicating that factors influencing technology adoption could vary with the organizational context.

Finally, one secondary attribute of innovations (incremental versus radical) has permitted us to define more adequately the degree of innovativeness of a firm. This redefinition of the degree of innovativeness permits a more subtle gradation capturing both a traditional measure (number of innovations) as well as the nature of these innovations. The score obtained in this manner appears to be preferable to the well-known Khandwalla score, based on fixed, pre-established criteria that do not take into account either the organizational context (multinationals versus small or medium-sized firms) or the sector (certain industrial sectors being more advanced than others with regard to the adoption of new technologies).

The results of this study are intended to better pin down and define the nature of the adoption and spread of new technologies in our manufacturing companies. In this respect, it is essential to point out the different dimensions of the role of the CEO during the adoption of new technologies. Perhaps we can now better understand one of the crucial factors in the adoption of new technologies in smaller manufacturing firms and ultimately formulate political choices and training programs capable of supporting and promoting efforts relating to the technological imperative.

Figure 1
Research Variables and their Operational Measures

Dependent value

degree of innovativeness	Inspired by Dewar and Dutton (1986) and Khandwalla (1977)

Independent variable

i) Personal characteristics of CEO

V1: firm's owner	Used by Khan and Manopichetwattana (1989)
V2: years in this sector	Used by Jarymiszyn et al. (1985)
V3: years as CEO	Used by Jarymiszyn et al. (1985)
V4: functional experience	Used by Collins et al. (1988)
V5: technical training	Used by Julien et al. (1988)
V6: level of education	Standard governmental classification

ii) Attitudes and personality traits of CEO

V7: attitude towards technological change	Used by Julien et al. (1988) and Nasbeth (1973)
V8: attitude towards risk	Adapted from Khan and Manopichetwattana (1989)
V9: proactive attitude	Adapted from Khan and Manopichetwattana (1989)
V10: locus of control	Used by Lumpkin (1988)

iii) Characteristics of CEOs decision-making process

V11: systematic external search for information	Adapted from Miller and Friesen (1982)
V12: systematic internal search for information	Adapted from Miller and Friesen (1982)
V13: futurity	Adapted from Khan and Manopichetwattana (1989)
V14: analytical ability	Adapted from Khan and Manopichetwattana (1989)
V15: strategic awareness	Adapted from Khan and Manopichetwattana (1989)

iv) Firm characteristics linked to CEOs influence

V16: technocratization	Used by Collins et al. (1988) and Julien et al. (1988)
V17: centralization	Used by Cohn and Turyn (1984) and Hage and Aiken (1970, 1967)
V18: formalization	Used by Cohn and Turyn (1984)

Figure 2
Typology of the innovations considered

Computer-based administrative applications

- Accounts payable/accounts receivable
- Inventory management
- Sales analysis
- Payroll
- Billing
- Cost accounting
- Operations management
- Word processing
- Electronic mail/electronic filing

Computer-based manufacturing applications

Production Technology

- Computer-assisted design (CAD) and/or Computer-assisted engineering (CAE)
- CAD output used to control manufacturing machines (CAD/CAM)
- Digital representation of CAD output used in procurement activities
- Artificial intelligence (AI) and/or expert systems (ES)

Fabrication and Assembly

- Flexible manufacturing cells (FMC) or systems (FMS)
- Numerical control machines (NC)
- Materials working lasers
- Pick and place robots
- Other robots

Automated Material Handling

- Automated storage and retrieval system (AS/RS)
- Automated guided vehicle system (AGVS)

Automated Sensor-Based Inspection and/or Test Equipment

- Performed on incoming or in-process materials
- Performed on final product

Communications and Control

- Local area network for technical data
- Local area network for factory use
- Inter company computer network linking plant to subcontractors
- Computers used for control on the factory floor

Manufacturing Information Systems

- Materials-requirements planning (MRP)
- Manufacturing resource planning (MRP)

Table 1

Comparative analysis of firms according to their degree of innovativeness (n = 74)

Independent variables	Less innovative firms (4)	More innovative firms (4)	Level of significance (5)
V1: firm's owner (%)	68.3	86.7	.037 *
V2: years in this sector	17.0	14.5	.166
V3: years as CEO	9.1	9.9	.349
V4: functional experience (1)			
in accounting/finances	5.2	3.9	.000 ***
in sales/marketing	5.1	4.9	.305
in engineering/production	3.1	5.5	.000 ***
in human resources	4.9	4.3	.055
V5: technical training (%)	7.1	50.0	.000 ***
V6: level of education (3)	1.7	2.0	.180
V7: attitude towards technological changes (1)	4.9	3.5	.005 **
V8: attitude towards risk (1)	2.8	4.9	.000 ***
V9: proactive attitude (1)	3.3	5.8	.000 ***
V10: locus of control (2)	4.0	2.7	.000 ***
V11: systematic external search for information (1)	3.4	4.6	.002 **
V12: systematic internal search for information (1)	4.1	5.6	.000 ***
V13: futurity (1)	3.2	5.0	.000 ***
V14: analytical ability (1)	2.9	4.8	.000 ***
V15: strategic awareness (1)	3.8	5.1	.001 **
V16: technocratization	2.1	9.3	.000 ***
V17: centralization (1)	5.8	6.0	.205
V18: formalization (1)	5.0	3.7	.001 **
Size (ln of annual sales)	15.9	15.6	.218

(1) Measured on 7 point Likert scale where 1 = lower values and 7 = higher values (with the exception of V7 which is a reversed scale).

(2) A low value indicates an internal locus of control whereas a high value indicates an external locus of control.

(3) Ordinal scale graduated from 0 to 5 indicating the achieved level of education where 0 corresponds to secondary school and 5 doctoral level studies.

(4) Sample is split into two halves according to the median value of the degree of innovativeness.

(5) Unilateral test: χ^2 test for variables V1 and V5 and t-test for remaining variables.

*** $p < 0.001$

** $p < 0.01$

* $p < 0.05$

Table 2

Results of factor analysis using varimax rotation (n = 74)

Independant variables	Factor 1	Factor 2	Factor 3	Factor 4
V2: years in this sector	- 0.26	0.21	**0.84**	0.06
V3: years as CEO	0.01	- 0.19	**0.82**	- 0.06
V4: functional experience in accounting/finances	- 0.48	**0.75**	0.07	- 0.11
in sales/marketing	- 0.22	**0.79**	0.07	- 0.04
in engineering/production	**0.81**	- 0.28	0.10	0.06
in human resources	- 0.16	**0.89**	- 0.10	0.01
V6: level of education	0.16	- 0.07	- 0.58	0.56
V8: attitude towards risk	**0.92**	- 0.12	- 0.21	0.01
V9: proactive attitude	**0.87**	- 0.24	- 0.13	0.18
V10: locus of control	- 0.72	0.14	0.04	- 0.26
V11: systematic external search for information	0.71	- 0.29	- 0.13	0.11
V12: systematic internal search for information	**0.91**	- 0.15	0.01	0.17
V13: futurity	**0.92**	- 0.16	- 0.09	- 0.02
V14: analytical ability	**0.88**	- 0.16	- 0.12	- 0.03
V15: strategic awareness	0.61	- 0.20	- 0.23	0.00
V16: technocratization	0.55	- 0.16	- 0.33	- 0.55
V17: centralization	0.31	- 0.12	- 0.08	**0.71**
V18: formalization	- 0.67	0.44	0.29	- 0.17
Cumulative percentage of explained variance	49.4%	59.9%	68.0%	74.6%

Kaiser-Meyer-Olkin measure = 0.80691 (sample adequacy test)

Table 3

Results of Iterative Discriminant Analysis
(n = 74)

Classification of "more innovative" and "less innovative" companies.

Three factors were retained in the following order:
factor 1 - "entrepreneurial characteristics"
factor 3 - "tenure" (number of years of service)
factor 2 - "administrative experience"

	predicted membership "less innovative"	"more innovative"
"less innovative"	70.4%	29.6%
actual membership		
"more innovative"	15.8%	84.2%

The discriminant function significantly differentiates between the two groups (p = 0.0000) and gives a global classification rate of 76.1%.
Box's M = 4.2 with a level of significance of 0.70 (1).

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(1) This test, also known as the matrix covariance equality test, allows us to accept the null hypothesis whereby the covariance matrices are equal. Considering the size of the sample, the hypothesis of multivariate normality is not rejected. Finally, there can be no multicollinearity beween the factors because the varimax rotation yields orthogonal factors. The fundamental hypotheses for carrying out a discriminant analysis are thus respected.

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